PB-240 700

PERFORMANCE OF THE ISCO MODEL 1391 WATER AND WASTEWATER SAMPLER

Richard P. Lauch

National Environmental Research Center
Cincinnati, Ohio

February 1975

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TECHNICAL REPORT DATA
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1. REPORT NO.	2.	3. PB 240 700
EPA-670/4-75-001		

4. TITLE AND SUBTITLE	5. REPORT DATE
PERFORMANCE OF THE ISCO MODEL 1391 WATER AND WASTEWATER SAMPLER	February 1975; Issuing Date
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Richard P. Lauch	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
National Environmental Research Center Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	1HA327; ROAP 24ALE; TASK 03
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Same as above	
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Samplers, Water pollution, Acceptance sampling, Continuous sampling, Data sampling, Sequential sampling	Sampler evaluation, Evaluation, Sewer sampler evaluation, Effluent sampler evaluation, Water sampler evaluation, Water sampler	13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to public	Unclassified	38
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	$3.75

☆ U.S. GOVERNMENT PRINTING OFFICE: 1975-657-590/5336 Region No. 5-11

EPA-670/4-75-001
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PERFORMANCE OF THE ISCO MODEL 1391 WATER AND WASTEWATER SAMPLER

By

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Methods Development and Quality Assurance Research Laboratory

Program Element No. 1HA327

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multi-disciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This report is part of a continued effort by the Instrumentation Development Branch, Methods Development and Quality Assurance Research Laboratory, NERC-Cincinnati, to evaluate instruments and provide information to both users and suppliers. Our efforts are also intended to result in upgraded instrumentation and the ability to choose the most suitable instrument for a particular application.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

Performance of the ISCO model 1391 water sampler was tested. Tests were run at 2, 19, and 35C to check accuracy and precision of the timer, flowmeter, and sample volumes. The multiplexer function of delivering multiple aliquots per bottle was tested. Performance checks were made on both converter and battery power, and battery endurance was determined. Discrete sample temperatures were recorded versus time under iced conditions. Manufacturer's claims were mostly confirmed, but improvement is warranted for some sampler components.

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SECTION I

CONCLUSIONS

The ISCO model 1391 sampler has an accurate timer. Timer precision is excellent for runs that are in multiples of 1 hour, however precision of other runs was not as good (approximately ±1 minute) and this variation is due to the manufacturer's method of initiating a signal from the timer. Existing precision is satisfactory for routine sampling; however, in special cases, such as litigation procedures, better precision may be required.

Occasionally spurious cycles occurred, which were caused by contact bounce of the timer actuated reed switch.

Volume of sample collected was satisfactory and variation in sample size was not excessive.

Multiplexer operation was satisfactory.

Flowmeter performance was satisfactory after calibration. Accurate calibration should take place at the factory. Flowmeter precision decreases with decreasing flows and is inherent for this type meter.

These runs showed no difference in operation between converter or battery power. Endurance tests showed that the company's claim for the sampler operation (collecting 100 samples of 500 ml each) was exceeded.

Thermocouple readings on discrete samples showed the company's claim of maintaining samples 22.2C below ambient for 24 hours is not always correct.

The pump did not reverse for eight samples of a low-temperature, high-humidity run. Changing the desiccant may have eliminated this problem.

SECTION II

RECOMMENDATIONS*

The model 1391 has many desirable features and would be satisfactory for routine sampling. Although existing timer precision is probably better than many other samplers on the market, improvement is still warranted. The possibility of taking a spurious sample should be eliminated. This could be accomplished by eliminating the reed switch and incorporating solid state logic circuits. Improvement in flowmeter precision at the low cam setting should be developed. A one-time factory flowmeter calibration is required. Desiccants can be burdensome, and samplers should be developed to perform satisfactorily without them. The sampler compartment should be kept light in weight and dimensionally small; however, better insulation and a larger ice space is required to keep iced samples for 24 hours when ambient temperatures are high.

The ISCO has many excellent features, and hopefully these recommendations will aid in the further development of water samplers.

*Correspondence from ISCO (November 20, 1974) states that the company markets a (model 1580) sampler that utilizes solid state programming electronics and that in time all ISCO samplers will utilize solid state programming electronics. This will replace the mechanical clock and programming relays including the reed switch. ISCO also stated that the problem experienced with the 15-minute timer on the model 1391 is not at all characteristic. A defective reed switch would usually show up during ISCO's quality assurance program checks and it would be replaced at that time. ISCO has also gone to a more sensitive and reliable reed switch for both the 15-minute and 10-minute timers.

SECTION III

DESCRIPTION OF SAMPLER

This report summarizes an evaluation of the ISCO water and wastewater sampler, which includes the following components:

1. Model 1391X sampler with 115 VAC/12 VDC power converter battery charger
2. Model 1392 Nicad battery pack (rechargeable)
3. Model 1406W high density polyethylene sample bottles (28 required)
4. Model 1397W 15-minute timer *in place of standard 30-minute timer*
5. Model 1398W multiplexer
6. Model 1470W flowmeter with 0- to 6-inch range and calibration disc for 90° sharp crested V-notch weir
7. Model 1396W suspension harness

Sampler weight is 40 pounds (18.16 Kg), not including the flowmeter.

This sampler will take up to 28 discrete samples. With the multiplexer, each discrete sample can be made up of from 1 to 4 aliquots. Aliquots may be timed from 15 minutes to 3 hours apart. For example, the device could be programmed to collect three 15-minute aliquots per discrete sample, and therefore the 28 bottles would be filled in 21 hours.

Power requirement is 12 VDC, which can be obtained from ISCO's 115 VAC/12 VDC power converter, their Model 1392 Nicad battery pack, or an automobile battery. The Nicad battery can be recharged with the power converter (time to full recharge is 14 hours).

The unit's electronic circuitry is transistorized and uses amplifier-driven relays incorporating switching and shunting transistor circuits. A multivibrator homes stepper relays after each cycle. One time-proportioned runs, the circuit is activated by a magnetically controlled reed switch. A four-lobe magnet mounted on the end of the clock shaft closes the reed switch four times per hour.

The unit tested included the Model 1470 flowmeter with 0- to 6-inch range and program disc for a 90° sharp crested V-notch weir.

This flowmeter is mounted upstream from a V-notch weir and will actuate the sampler proportional to flow. Sample size remains constant, but time between samples varies. The multiplexer may also be used with the flowmeter, allowing up to 4 aliquots per discrete sample. Flowmeter electronics includes a pulse generator, which delivers a 13.66 Hz signal whenever the float-driven stylus is in contact with the conductive portion of the disc. This signal enters a binary counter that triggers a 12-volt signal after a specified number of pulses determined by the range-switch setting. This 12-volt signal which is proportional to flow, will now actuate the sampler instead of the clock-activated reed switch mentioned in the previous paragraph. Complete operational descriptions, including circuit diagrams, are provided by the manufacturer with instrument purchase.

SECTION IV

METHOD OF TESTING AND EQUIPMENT USED

Testing took place in the laboratory under ambient conditions and also within an environmental chamber at temperatures of 2, 19, and 35C. When the environmental chamber was used for time-controlled runs, both the sampler and water tub were located within the chamber. For flowmeter-controlled runs, the sampler and flowmeter were located within the chamber, but lack of space made it necessary to place the water tub outside. Therefore, during all flowmeter runs, the sample water temperature was maintained at ambient (about 20C). Lift from the water tub to the pump inlet was maintained at 3 feet (91.4 cm) for all runs. Flowmeter runs were made under static conditions with the meter mounted on a tub of still water. Float settlings were adjusted by varying the water level within the tub. Figure 1 illustrates the setup for testing the flowmeter/sampler combination within the environmental chamber.

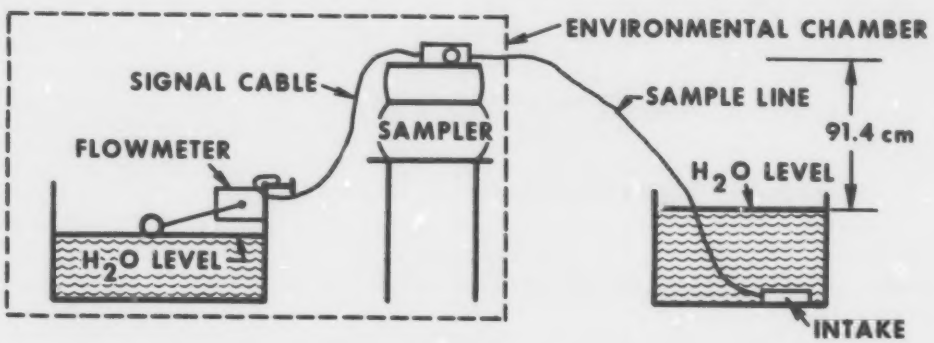

Figure 1. SCHEMATIC DIAGRAM OF FLOWMETER/SAMPLER TESTS WITHIN THE ENVIRONMENTAL CHAMBER

Some of the environmental chamber runs were made to show preservation ability, and therefore thermocouples were located inside eight of the 28 sample bottles. Thermocouple locations are shown in Figure 2. Before these runs, the center of the sample container was filled with ice and enough water to cover the lower portion of the bottles.

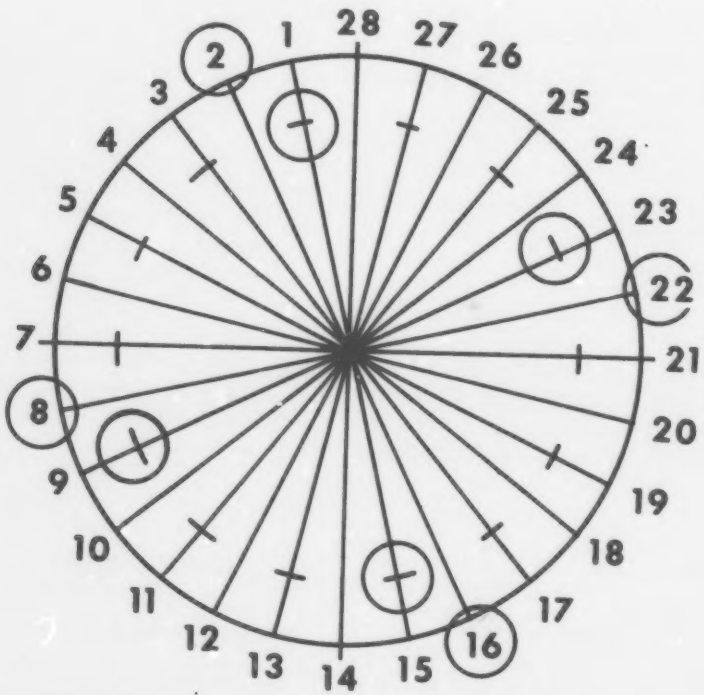

Fig.2 Thermocouple locations.

Equipment used for the sampler evaluation is as follows:

1. Honeywell Electronic 16 recorder (span to 12 volts with suppression)
2. Esterline Angus recorder (span to 100 volts)
3. Honeywell Electronic 16, 12 point thermocouple recorder
4. Webber Manufacturing Company, Inc., environmental chamber
5. Resistance decades

6. Tektronix Model 454A oscilloscope
7. Matheson thermometer, -1 to 51C, 1/10 division
8. Various graduates and flasks

Recorders (other than temperature) were used to monitor voltages across the pump motor (C12) and after the reed switch (across R4). Components C12 and R4 are shown in the manufacturer's circuit diagram, which is not included in this report. The C12 trace gave an accurate record of pump operation (forward and reverse) versus time. The R4 trace gave an accurate record of either the reed switch movement or the flowmeter signal, residual voltages, and also pump operation versus time. Oscilloscope observations included the multivibrator signals, flowmeter frequency, and various voltage levels within the electronics. Various flasks and graduates were used to measure the sample volumes collected.

SECTION V

RESULTS OF PERFORMANCE TESTS

TIMED RUNS

Accuracy of the timing function and volume delivery was tested at approximately 2, 19, and 35C. Table 1 summarizes this part of the original data, which are included as Tables 5 through 12 of the Appendix. For example, Table 1 shows that run no. 5 was made with the sampler and water bath in the environmental chamber at 1.7C. Average volume (X) of the 28 bottles collected was 440.5 ml (standard deviation S_X, = 2.33 ml), and average time (t) between bottles was 44.99 minutes (S_t = 0.809 minute). Sampler settings were 420 ml and 45 minutes for volume and time, respectively. For this run, the average volume collected was satisfactory and volume variation was not excessive. Average time between samples (44.99 minutes) is near perfect, hence the clock is an accurate timing device; however the standard deviation of 0.809 minutes shows a lack of precision. This variation in time between discrete samples can be seen in Table 9 of the Appendix. Time variation is caused by the four-lobe magnet (described earlier) that closes a reed switch and initiates a pulse four times per hour. Better time precision between samples can be maintained if each lobe were exactly 90° apart, with precise magnetic field intensity. Table 1, run no. 3, shows a run set to collect samples 60 minutes apart. Here, each cycle was initiated by the same magnet lobe after 360° of rotation, and excellent precision (S_t = .021) is maintained. Discrete sample time variation for this run can be seen in Table 7 of the Appendix.

Run no. 8 in Table 1 shows a volume standard deviation of 6.3 ml. This is higher than for other runs and was probably caused by improper placement of the sample line. The line should be installed with a slight downward slope from the sampler to the source. This point is mentioned by the manufacturer in his instruction manual.

Multiplexer operation on a timed cycle was checked at ambient conditions (approximately 20C). The sampler was programmed to collect three 140-ml aliquots per bottle at 15 minute intervals. Therefore, the distribution funnel indexes to the next bottle every 45 minutes. Table 2 illustrates this run. Average sample volume of 424.7 ml is satisfactory when compared to the setting of 420 (3 x 140).

Table 1. SAMPLER ACCURACY (TIMED RUNS)*

Run no.	Temp. (°C)	Volume			Time		
		Set	$\bar{X}$ (ml)	S_x (ml)	Set	$\bar{t}$ (min)	S_t (min)
			115 VAC/12 VDC Converted				
5	1.7	420	440.5	2.33	45	44.99	0.809
8	19.4	420	440.1	6.30	45	45.00	0.823
2	21.0	210	220.6	1.81	45	45.01	0.560
6	32.8	420	441.4	2.331	45	44.99	0.828
3	22.0	210	216.4	1.069	60	59.99	0.021
1	21.0	210	219.5	2.13	15	15.00	0.557
			12 V Battery				
4	1.7	420	438.6	3.56	45	45.00	0.828
7	34.7	420	437.4	2.329	45	45.00	0.836

*Averages ($\bar{X}$ and $\bar{t}$) and standard deviations (S_x and S_t) were calculated from 28 samples.

Sample variation (Std. Dev. = 1.63) is not excessive. Timer accuracy was satisfactory with an average interval between aliquots of 15 minutes and average time per sample of 45 minutes. Time variation, again caused by the magnet lobes, can be improved.

FLOWMETER

The flowmeter/sampler combination was tested on both converter and battery power at temperatures of approximately 2, 19, and 35C. The multiplexer was also used on some of these runs. Table 3 summarizes the original flowmeter data, which are included as Tables 13 through 21 of the Appendix. As an example, run no. 9 in Table 3 shows that the sampler was set to collect 280 ml per bottle after each 4,000 gallons of flow passed over the weir. Twenty-eight samples contained an average of 302.1 ml, with a standard deviation of 1.88 ml; hence sample volume is satisfactory and variation is not excessive. Average time between samples was 37.71 minutes, giving a flowmeter reading of 106.1 gpm. Flow calculated from the weir equation ($Q = 5/2H^{5/2}$) was 113.5 gpm,

Table 2. TIMED MULTIPLEXER OPERATION*

Time (min)				
Aliquot #1	Aliquot #2	Aliquot #3	Sample Total	Volume (ml)
15.50†	14.25	15.85	45.60	425
14.55	15.55	14.15	44.25	423
15.80	14.45	15.55	45.80	425
14.10	15.95	14.45	44.50	423
15.40	14.15	15.85	45.40	423
14.45	15.55	14.20	44.20	424
15.75	14.50	15.50	45.75	421
14.25	15.85	14.45	44.55	425
15.55	14.10	15.80	45.45	423
14.45	15.50	14.15	44.10	424
15.85	14.50	15.35	45.70	425
14.30	15.70	14.50	44.50	423
15.50	14.20	15.80	45.50	425
14.50	15.55	14.20	44.25	425
15.80	14.45	15.50	45.75	423
14.15	15.80	14.55	44.50	424
15.50	14.20	15.80	45.50	426
14.45	15.50	14.20	44.15	425
15.80	14.55	15.45	45.80	424
14.20	15.85	14.55	44.60	426
15.45	14.20	15.75	45.40	427
14.55	15.55	14.20	44.30	425
15.80	14.45	15.55	45.80	429
14.20	15.80	14.50	44.50	425
15.55	14.20	15.70	45.45	425
14.50	15.50	14.30	44.30	427
15.70	14.55	15.50	45.75	427
14.45	15.80	14.55	44.80	425
Avg = 15.00	15.007	14.996	45.005	424.7
S = .668	.699	.675	.649	1.63

*Sampler programmed to collect three 140 ml aliquots per bottle at 15-minute intervals.
†Estimated.

using the head of 0.4 foot. This differs from the manufacturer by 6.5 percent and exceeds their 5 percent claim. The manufacturer suggested adjusting the unit if necessary so that the stylus just touches the disc conductor when the meter reads zero. The manufacturer's setting was slightly low, so the adjustment was made. Table 3 shows that the adjustment was beneficial, except that the very lowest readings (runs 17 and 18) were then slightly high. Figure 3 illustrates the flowmeter versus weir equation before and after the zero adjustment. This adjustment is hard to set because it is in a confined area and should be made at the factory.

Table 3 shows that the standard deviation (S_t) for time between samples gets larger as flow decreases. This is inherent for this type of flowmeter, that incorporates a 13.66 pps signal that is being generated and integrated only while the stylus makes contact with the disc conductor. Contact time per disc revolution becomes proportionately less as flow decreases.

Table 3 shows that multiplexer operation (run nos. 11, 12, 13) on flow-proportional runs is satisfactory for volumes and volume variation. Flowmeter accuracy for these runs was discussed above.

BATTERY OPERATION AND ENDURANCE

Table 1 (timed runs) and Table 3 (flowmeter runs) show that the difference between converter and battery operation is not significant. Satisfactory operation should therefore be expected when operating on either converter or battery power for both timed and flowmeter runs.

The 1392W nickel-cadmium battery supplied by ISCO was tested for compliance with their claim (100 samples of 500 ml each after a 14-hour recharge). The battery was recharged for more than 14 hours before starting the endurance tests. The sampler was placed at a lift of 3 feet (91.44 cm) and set to collect 490 ml samples at 15-minute intervals. These tests showed that the battery operated the unit through nine complete runs with over 500 ml per sample being collected (252 samples). Battery endurance therefore exceeded the company's specification and is satisfactory.

TEMPERATURE PRESERVATION

ISCO's sample bottle tub incorporates an inner and outer liner

Table 3. FLOWMETER ACCURACY

Run no.	Temp. (°C)	Comments	Sample volume (ml) Set	Avg. $\bar{x}$	Std. dev. S_x	Time between samples Set (gal/sample)	$\bar{t}_1$ (min)	S_1 (min)	$\bar{t}_2$ (min)	S_2 (min)	$\bar{t}_t$ (min)	S_t (min)	Flow Weir hd. (ft)	$5/2(H)^{5/2}$ (gal/min)	Flowmeter (gal/min)
9	20	1	280	302.1	1.88	4000	---	---	---	---	37.71	0.154	0.4	113.5	106.1
10	20	1	280	302.6	0.79	500	---	---	---	---	9.69	0.277	0.3	55.2	51.6
11	20	1,3	210	454.9	1.69	250	12.68	0.247	12.76	0.290	25.44	0.341	0.2	20.2	19.7
						After zero adjustment									
12	20	2,3	210	455.2	1.47	2000	17.24	0.326	17.11	0.441	34.35	0.192	0.4	113.6	116.5
13	20	2,3	210	455.3	1.18	2000	17.53	0.388	17.45	0.352	34.97	0.192	0.4	113.6	114.4
15	1.7	1	350	371.6	1.62	1000	---	---	---	---	6.51	0.121	0.451	153.3	153.6
16	1.1	2	350	365.9	3.13	1000	---	---	---	---	6.52	0.102	0.451	153.3	153.4
17	36	1	350	370.9	1.32	62.5	---	---	---	---	5.52	0.326	0.15	9.78	11.32
18	35	2	350	369.4	1.40	62.5	---	---	---	---	5.29	0.554	0.15	9.78	11.81

1 115 VAC to 12 VDC converter
2 12 V battery
3 multiplexer

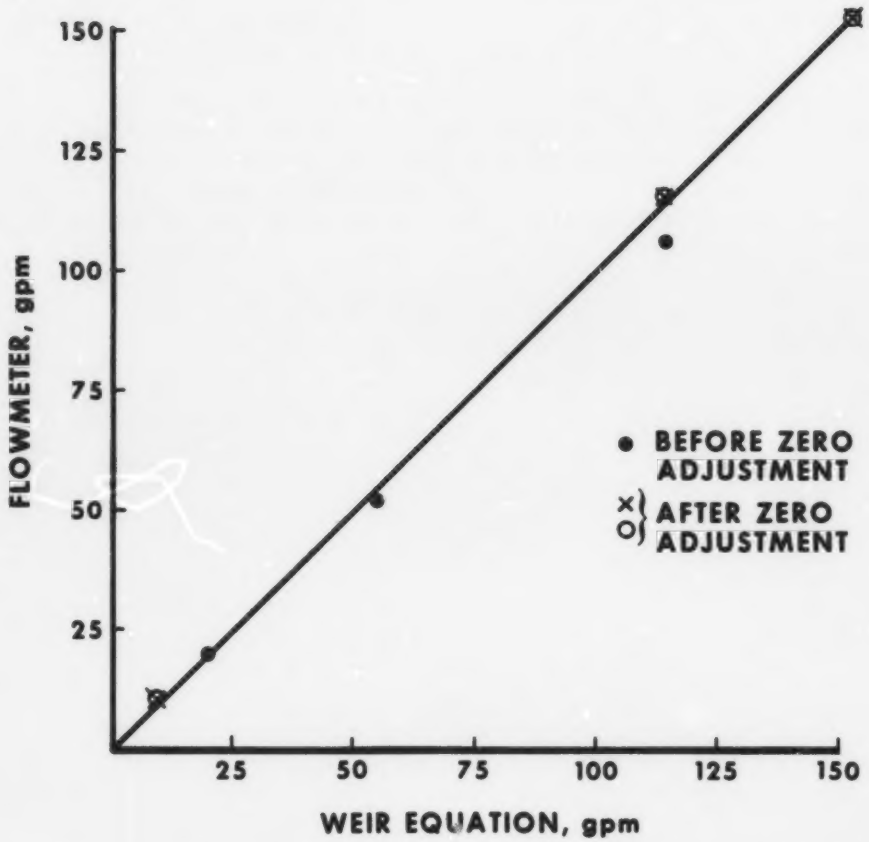

Figure 3. FLOWMETER VERSUS WEIR EQUATION

separated by polyurethane foam insulation. As mentioned earlier (Figure 2), these tests were made with thermocouples located in bottle numbers 1, 2, 8, 9, 15, 16, 22, and 23, and the center of the container was packed with ice. Sample temperatures are plotted versus time in Figures 4 and 5 for environmental chamber runs at 33 and 19C, respectively. Figure 4 shows sample temperatures decreasing with time and then increasing as the ice melted. A minimum temperature of about 7C is shown in Figure 4 and a minimum of about 4C is shown in Figure 5. The fact that some samples (such as no. 9 in Figure 4) show the temperature decreasing immediately (from 31 to 5.5C) indicates that the thermocouple was probably resting against the side of the bottle. The more gradual slope shown for most samples is a truer picture of sample water temperature. Company claims are that the sampler, when packed with ice, will hold samples 22.3C below ambient for 24 hours. Figure 4 shows that this claim is not necessarily true. EPA methods* require a preservation temperature of 4C for some measurements.

*"Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, NERC, AQCL, Cincinnati, Ohio, 1971.

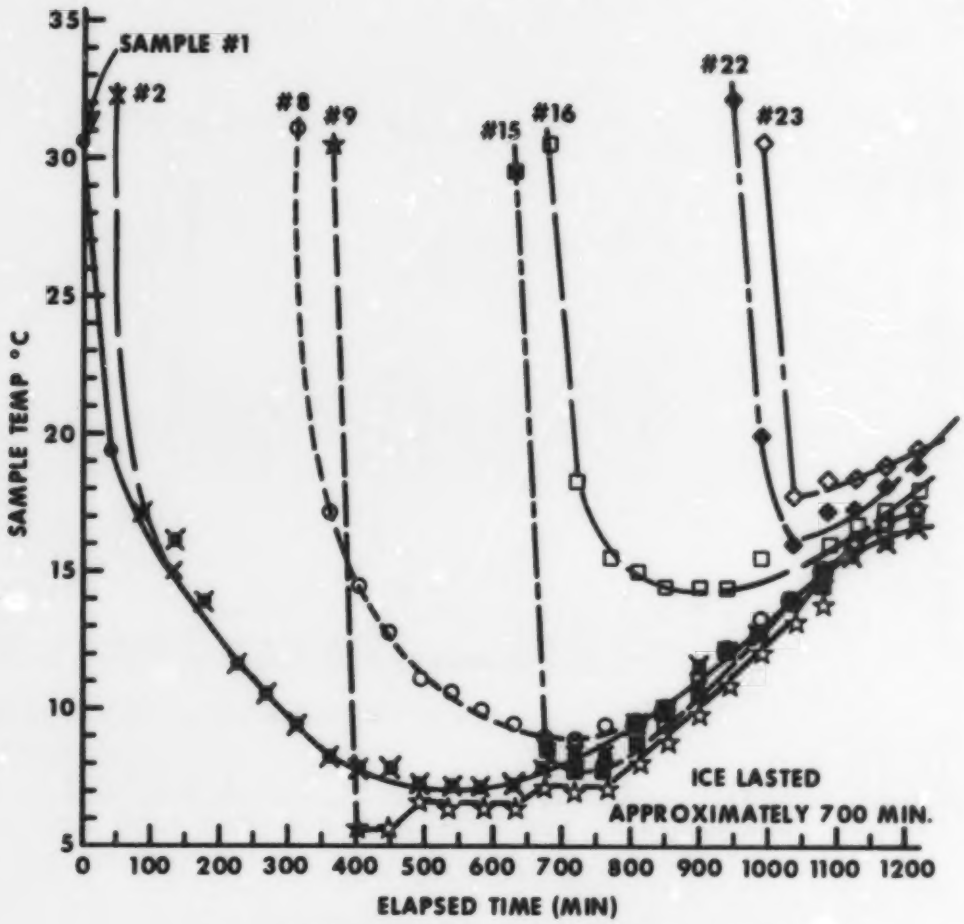

FIG. 4 DISCRETE SAMPLE TEMP VS. TIME
(CHAMBER TEMP. AT 33°C)

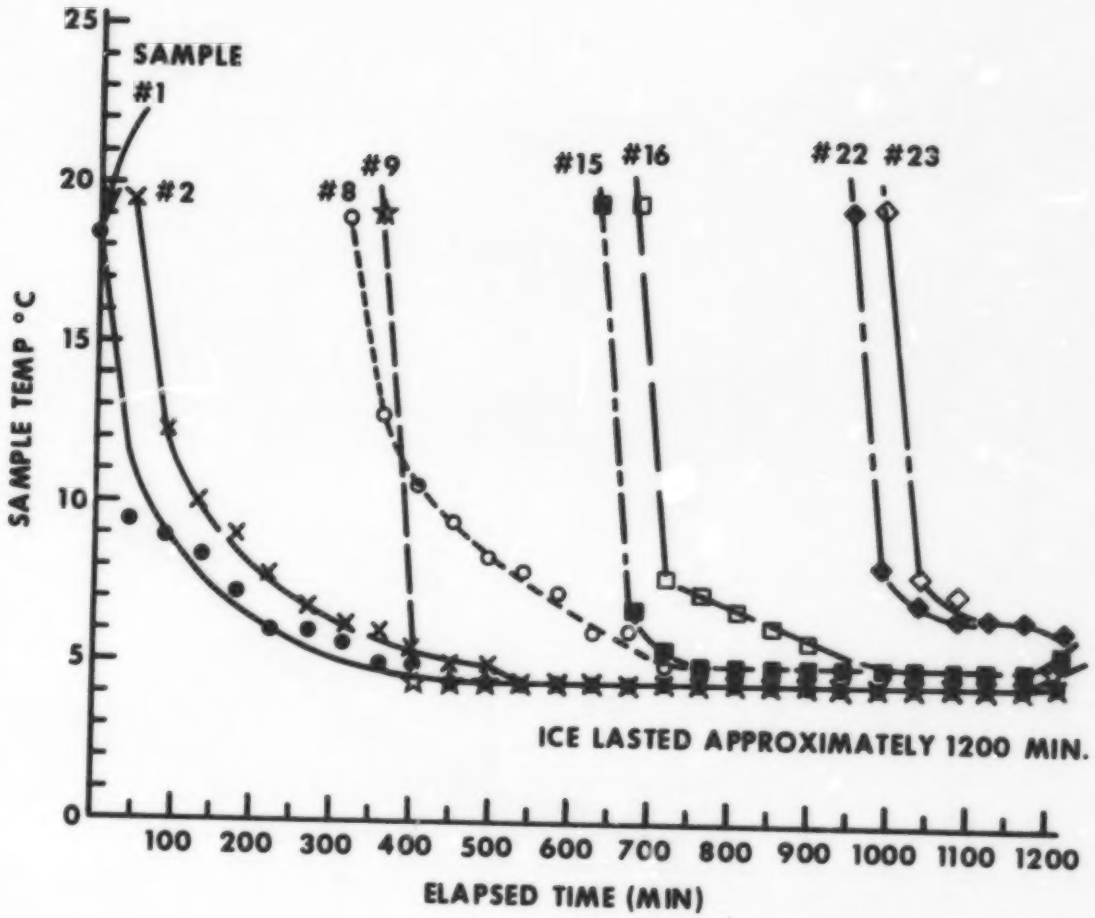

FIG. 5 DISCRETE SAMPLE TEMP. VS. TIME
(CHAMBER TEMP. AT 19°C)

SECTION VI

PROBLEMS

SPURIOUS CYCLES

A few spurious cycles occurred when these tests were initiated. The problem was traced to the magnetically actuated reed switch, which closes every 15 minutes, stays closed for about 10 minutes, and then reopens. At times, just after reopening, the reed switch reclosed and initiated a spurious signal. Table 4 illustrates this phenomenon occurring during a run with the multiplexer and timer set on 3 and 15 minutes, respectively. In this instance, two aliquots are taken within the 15-minute time period, and every aliquot thereafter is taken 15 minutes earlier. This problem was intermittent; and after inspecting the magnet and reed switch and reinstalling them, it did not reoccur. A slightly different positioning of these components may have inadvertently corrected the problem, however these components should be redesigned so that the problem never occurs.

PUMP REVERSAL

One run occurred in which the pump did not reverse for the first eight samples (Appendix Table 18), and the bottles therefore overflowed. This run was made using the flowmeter and sampler within the environmental chamber at 2C. Relative humidity within the chamber was approximately 100 percent. Moisture may have caused the problem, since the desiccant was changed after the run, and the problem did not reoccur. Samplers should be designed to work properly without the use of desiccants because it is too easy to forget to change them.

SUSPENDED SOLIDS

The sampler incorporates an inlet strainer that is a cylinder (1 inch [2.54 cm] ID and 5 inches [12.7 cm] long). The cylinder has four rows (90° apart) of five 1/4-inch (.635 cm) diameter holes. Either 3/8- or 1/4-inch diameter tubing is used to carry the sample from the strainer to the unit. Average velocity within the 1/4-inch line was measured with a stop watch at 0.79 (24.08 cm) per second. Suspended solids of an organic nature should stay in suspension at this velocity. Velocity through each of the 20 strainer holes would be 1/20 of 0.79 foot per second, and the

Table 4. SPURIOUS CYCLES*

Sample number	Time (min)			
	Aliquot #1	Aliquot #2	Aliquot #3	Sample total
1	14.35†	15.4	14.4	44.15
2	15.9	14.3	15.5	45.70
3	14.3	15.9	14.3	44.50
4	15.35	14.4	15.85	45.60
5	14.35	15.35	14.45	44.15
6	15.85	14.35	15.35	45.55
7	14.4	15.85	14.35	44.60
8	15.4	14.45	15.8	45.65
9	14.3	15.4	---	---
10	15.9	14.3	15.45	45.65
11	14.4	15.85	[8.7	38.95
12	5.65]	15.45	14.3	35.40
13	15.9	14.3	15.45	45.65
14	14.35	15.9	14.35	44.60
15	15.4	14.35	15.85	45.60
16	14.35	15.45	14.35	44.15
17	15.85	14.35	15.4	45.60
18	14.35	[9.95	5.95]	30.25
19	14.35	15.4	---	---
20	15.9	14.45	15.35	45.70
21	14.4	[9.85	6.0]	30.25
22	14.4	15.35	14.4	44.15
23	15.9	---	15.25	---
24	14.5	15.85	14.4	44.75
25	15.35	14.45	15.8	45.60
26	14.4	15.3	14.45	44.15
27	15.8	14.4	15.35	45.55
28	14.4	[9.8	5.0]	30.20

*Brackets show where two aliquots were taken during a 15-minute period. The sampler was programmed to take one aliquot every 15 minutes.
†Estimated.

velocity within the 1-inch ID strainer is also proportionately lower than 0.79. Accurate suspended solids samples could probably be obtained if the strainer were removed and the 1/4-inch tube opening directed toward the flow. Recently ISCO came out with a model 1392 sampler which pumps at a rate four times faster than the model 1391.

SECTION VII

DISCUSSION

Performance was satisfactory during most of these tests. Weight and dimensions make the sampler easy to handle and adaptable to most locations, including manholes. The control function is professionally designed and neatly assembled, using transistorized circuitry mounted on printed circuit boards. Greater use of "plug-in" components and circuits should be incorporated. Although the electromechanical switches performed satisfactorily, except for the reed switch, one may consider replacing these components with integrated solid state logic circuits. Components should be designed for operation in humid environments, and desiccants should be eliminated. The small, light-weight, rechargeable battery performed well and is a desirable feature. An event recorder should be included to mark the time that the sample was taken on both time- and flow-proportioned runs. The manufacturer's instruction manual is thorough, includes circuit diagrams, and is easy to follow. In general, the model 1391 is an above-average sampler, and it is hoped that the recommendations made in this report will be considered objectively.

SECTION VIII

APPENDIX

Table 5. TIMED TESTS, RUN #1*

Sample number	Cycle time t (min)	Volume x (ml)
1	15.75†	220
2	14.50	222
3	15.25	219
4	14.50	220
5	15.75	221
6	14.50	218
7	15.30	221
8	14.50	221
9	15.75	217
10	14.50	216
11	15.25	216
12	14.50	218
13	15.75	219
14	14.50	221
15	15.30	219
16	14.40	219
17	15.80	222
18	14.50	218
19	15.30	221
20	14.45	222
21	15.75	217
22	14.50	216
23	15.25	221
24	14.50	222
25	15.85	221
26	14.45	222
27	15.20	216
28	14.50	222
Total	420.05	---

$\bar{t}$ = 15.00 $\bar{x}$ = 219.50
S_t = 0.557 S_x = 2.13

*Room temperature is 21°C; water temperature is 18°C.
†Estimated.

Table 6. TIMED TESTS, RUN #2*

Sample number	Cycle time t (min)	Volume x (ml)
1	45.50†	218
2	45.50	222
3	44.20	221
4	45.60	222
5	45.50†	223
6	44.25	221
7	45.40	219
8	44.70	217
9	45.50	221
10	44.25	222
11	45.50	218
12	44.80	220
13	45.50	222
14	44.20	222
15	45.50	221
16	44.75	218
17	45.50	218
18	44.25	221
19	45.50	222
20	44.70	220
21	45.50	221
22	44.20	222
23	45.50	220
24	44.70	222
25	45.50	218
26	44.20	224
27	45.50	222
28	44.70	219
Total	1260.40	---

$\bar{t}$ = 45.01 $\bar{x}$ = 220.60
S_t = 0.560 S_x = 1.814

*Room temperature is 21°C; water temperature is 18°C.
†Estimated.

Table 7. TIMED TESTS, RUN #3*

Sample number	Cycle time t (min)	Volume x (ml)
1	60.0†	218
2	60.0	218
3	60.0	216
4	60.0	217
5	60.0	217
6	60.0	217
7	60.0	217
8	59.95	216
9	60.0	218
10	60.0	216
11	60.0	215
12	59.95	216
13	60.0	215
14	60.0	216
15	59.95	217
16	60.0	217
17	60.0	215
18	60.0	216
19	60.0	216
20	59.95	214
21	59.95	218
22	60.0	215
23	60.0	216
24	59.95	218
25	60.0	217
26	60.0	216
27	60.0	217
28	60.0	216
Total	1679.7	---

$\bar{t}$ = 59.99 $\bar{x}$ = 216.4
S_t = 0.021 S_x = 1.069

*Room temperature is 22°C; water temperature is 19°C.
†Estimated.

Table 8. TIMED TESTS, RUN #4*

Sample number	Cycle time t (min)	Volume x (ml)
1	44.1†	440†
2	45.7	440
3	44.3	455
4	45.9	437
5	44.1	439
6	45.6	440
7	44.5	439
8	45.7	439
9	44.3	439
10	45.8	440
11	44.2	437
12	45.8	435
13	44.1	436
14	45.8	437
15	44.3	440
16	45.8	437
17	44.1	437
18	45.7	438
19	44.3	437
20	46.0	438
21	44.0	439
22	45.8	437
23	44.3	438
24	45.8	434
25	44.1	438
26	46.0	439
27	44.1	438
28	45.9	437
Total	1260.1	---

$\bar{t}$ = 45.00 $\bar{x}$ = 438.6
S_t = 0.828 S_x = 3.56

*Chamber temperature is 2°C; water temperature is 3°C. Battery power.
†Estimated.

Table 9. TIMED TESTS, RUN #5*

Sample number	Cycle time t (min)	Volume x (ml)
1	44.2†	445
2	45.7	438
3	44.1	440
4	46.0	441
5	44.2	440
6	45.8	441
7	44.0	438
8	46.0	438
9	44.2	441
10	45.8	440
11	44.0	441
12	45.8	437
13	44.4	440
14	45.7	438
15	44.1	443
16	46.0	442
17	44.0	440
18	46.0	441
19	44.0	438
20	46.0	437
21	44.2	442
22	45.8	439
23	44.0	438
24	46.0	442
25	44.2	445
26	45.8	441
27	44.0	443
28	45.7	445
Total	1259.7	---

$\bar{t}$ = 44.99 $\bar{x}$ = 440.5
S_t = 0.809 S_x = 2.33

*Chamber temperature is 2°C; water temperature is 3°C.
†Estimated.

Table 10. TIMED TESTS, RUN #6*

Sample number	Cycle time t (min)	Volume x (ml)
1	45.7†	440†
2	44.0	445
3	46.0	443
4	44.2	443
5	45.9	444
6	43.9	443
7	45.9	444
8	44.5	440
9	45.7	444
10	43.9	444
11	45.9	438
12	44.4	440
13	45.7	442
14	44.1	440
15	45.7	443
16	44.3	439
17	45.7	435
18	44.0	444
19	45.8	443
20	44.4	439
21	45.8	441
22	44.0	440
23	45.8	440
24	44.5	439
25	45.5	442
26	44.0	440
27	45.8	441
28	44.5	443
Total	1259.6	---

$\bar{t}$ = 44.99 $\bar{x}$ = 441.4
S_t = 0.828 S_x = 2.331

*Chamber temperature is 33°C; water temperature is 30°C.
†Estimated.

Table 11. TIMED TESTS, RUN #7*

Sample number	Cycle time t (min)	Volume x (ml)
1	44.3†	440†
2	45.8	440
3	44.0	440
4	45.9	434
5	44.3	438
6	45.8	439
7	44.2	440
8	45.9	433
9	44.4	441
10	45.7	436
11	44.2	439
12	48.0	437
13	45.1	440
14	46.2	438
15	44.0	438
16	45.9	434
17	44.3	435
18	45.7	438
19	44.0	436
20	46.0	436
21	44.2	437
22	45.8	433
23	43.9	439
24	45.9	435
25	44.4	436
26	45.6	436
27	44.2	438
28	45.8	440
Total	1260.1	---

$\bar{t}$ = 45.00 $\bar{x}$ = 437.4
S_t = 0.836 S_x = 2.329

*Chamber temperature is 35°C; water temperature is 33°C. Battery power.
†Estimated.

Table 12. TIMED TESTS, RUN #8*

Sample number	Cycle time t (min)	Volume x (ml)
1	45.75†	440†
2	44.2	445
3	45.8	435
4	44.3	441
5	45.8	443
6	44.2	442
7	45.7	438
8	44.3	455
9	45.7	436
10	44.2	436
11	46.0	455
12	44.3	441
13	45.6	440
14	44.0	458
15	45.9	434
16	44.2	437
17	45.8	436
18	44.1	434
19	45.9	438
20	44.2	436
21	45.8	440
22	44.1	438
23	45.9	435
24	44.2	438
25	45.8	437
26	44.1	443
27	45.8	435
28	44.4	438
Total	1260.05	---

$\bar{t}$ = 45.00 $\bar{x}$ = 440.1
S_t = 0.823 S_x = 6.299

*Chamber temperature is 20°C; water temperature is 20°C.
†Estimated.

Table 13. FLOWMETER TESTS, RUN #9*

Sample number	Cycle time t (min)	Volume x (ml)
1	----	307
2	37.8	300
3	37.5	301
4	37.8	302
5	37.9	300
6	37.8	303
7	37.7	302
8	37.5	303
9	38.0	302
10	37.7	299
11	37.6	300
12	37.7	302
13	37.8	303
14	37.5	304
15	37.7	303
16	37.6	302
17	37.7	304
18	38.2	303
19	37.5	300
20	37.6	303
21	37.7	300
22	37.7	300
23	37.6	300
24	37.7	301
25	37.7	304
26	37.7	305
27	37.7	304
28	37.7	303
Total	1018.1	---

$\bar{t}$ = 37.71 $\bar{x}$ = 302.1
S_t = 0.154 S_x = 1.88

*Flowmeter setting = 4000 gal/sample. Head = 0.4 ft. Flowmeter gave 106.1 gal/min. Weir equation gave 113.5 gal/min. Room temperature = 21°C.

Table 14. FLOWMETER TESTS, RUN #10*

Sample number	Cycle time t (min)	Volume x (ml)
1	----	303
2	9.7	304
3	9.55	303
4	10.3	303
5	9.45	304
6	9.65	303
7	9.65	303
8	9.55	302
9	9.55	303
10	10.35	303
11	9.5	303
12	9.6	302
13	9.6	303
14	9.55	303
15	9.55	302
16	9.55	303
17	10.3	301
18	9.6	303
19	9.65	303
20	9.55	303
21	9.55	302
22	9.6	303
23	9.5	302
24	10.35	302
25	9.55	301
26	9.55	303
27	9.55	301
28	9.65	302
Total	261.5	---

$\bar{t}$ = 9.685 $\bar{x}$ = 302.61
S_t = 0.277 S_x = 0.786

*Flowmeter setting = 500 gal/sample. Head = 0.3 ft. Flowmeter gave 51.63 gal/min. Weir equation gave 55.21 gal/min. Room temperature = 21°C.

Table 15. FLOWMETER TESTS, RUN #11*

Sample number	Time 1st aliquot t (min)	Time 2nd aliquot t (min)	Accumulative time t (min)	Volume x (ml)
1	----	12.7	25.4	459
2	12.6	12.7	25.3	455
3	12.7	12.8	25.5	457
4	12.5	12.7	25.2	453
5	12.6	12.9	25.5	453
6	13.5	12.6	26.1	457
7	12.6	12.8	25.4	456
8	12.6	12.7	25.3	453
9	12.7	12.5	25.2	457
10	12.6	12.6	25.2	455
11	12.6	13.6	26.2	453
12	12.7	12.5	25.2	457
13	12.9	12.6	25.5	455
14	12.6	12.7	25.3	455
15	12.6	12.6	25.2	454
16	12.7	13.5	26.2	455
17	12.7	12.7	25.4	456
18	12.5	12.6	25.1	455
19	12.5	12.7	25.2	453
20	12.6	13.5	26.1	453
21	12.5	12.8	25.3	455
22	12.6	12.8	25.4	455
23	12.5	12.7	25.2	454
24	12.6	12.7	25.3	457
25	13.5	12.5	26.0	452
26	12.6	12.6	25.2	453
27	12.6	12.6	25.2	454
28	12.6	12.6	25.2	455
Total	342.3	357.3	----	---
	$\bar{t}$ = 12.68	$\bar{t}$ = 12.76	$\bar{t}$ = 25.44	$\bar{x}$ = 454.86
	S_t = 0.247	S_t = 0.290	S_t = 0.341	S_x = 1.693

*Flowmeter setting = 250 gal/sample.
Head = 0.2 ft.
Flowmeter gave 19.65 gal/min.
Weir equation gave 20.2 gal/min.
Room temperature is 21°C.

Table 16. FLOWMETER TESTS, RUN #12*

Sample number	Time 1st aliquot t (min)	Time 2nd aliquot t (min)	Accumulative time t (min)	Volume x (ml)
1	----	17.3	34.6	458
2	17.3	16.8	34.1	458
3	17.2	16.8	34.0	453
4	17.2	17.0	34.2	457
5	17.3	17.0	34.3	456
6	16.8	17.2	34.0	453
7	17.3	17.0	34.3	456
8	18.4	19.0	37.4	455
9	17.3	17.0	34.3	453
10	17.3	16.7	34.0	456
11	17.4	16.9	34.3	455
12	17.4	16.7	34.1	455
13	17.2	16.9	34.1	457
14	17.2	16.8	34.0	457
15	17.5	16.7	34.2	454
16	17.3	17.4	34.7	455
17	16.7	17.3	34.0	456
18	16.9	17.4	34.3	455
19	16.8	17.2	34.0	455
20	17.0	17.1	34.1	454
21	16.8	17.2	34.0	453
22	17.0	17.2	34.2	453
23	17.3	16.9	34.2	455
24	17.1	16.9	34.0	455
25	17.4	16.9	34.3	455
26	17.3	16.9	34.2	456
27	17.3	17.5	34.8	454
28	17.7	17.5	35.2	456
Total	465.4	479.2	----	---
	$\bar{t}$ = 17.24	$\bar{t}$ = 17.11	$\bar{t}$ = 34.35	$\bar{x}$ = 455.18
	S_t = 0.326	S_t = 0.441	S_t = 0.192	S_x = 1.467

*Flowmeter setting = 2000 gal/sample.
Head = 0.4 ft.
Flowmeter gave 16.48 gal/min.
Weir equation gave 113.55 gal/min.
Calibration cam adjusted before run.
Battery power.
Room temperature is 21°C.

Table 17. FLOWMETER TESTS, RUN #13*

Sample number	Time 1st aliquot t (min)	Time 2nd aliquot t (min)	Accumulative time t (min)	Volume x (ml)
1	----	18.1	35.6	455
2	19.0	18.5	37.5	456
3	17.5	17.1	34.6	456
4	17.6	16.9	34.5	458
5	17.6	17.6	35.2	456
6	16.8	17.4	34.2	456
7	17.6	17.4	35.0	455
8	17.0	17.6	34.6	452
9	17.4	17.5	34.9	456
10	17.4	17.1	34.5	456
11	17.5	17.5	35.0	455
12	17.3	17.5	34.8	456
13	17.5	17.2	34.7	456
14	17.6	17.2	34.8	455
15	17.7	17.1	34.8	455
16	17.7	17.2	34.9	456
17	17.3	17.3	34.6	455
18	17.9	17.3	35.2	457
19	17.2	17.5	34.7	456
20	17.8	17.2	35.0	453
21	17.3	18.0	35.3	455
22	17.5	17.4	34.9	453
23	17.3	17.8	35.1	455
24	17.4	17.1	34.5	455
25	18.0	17.5	35.5	455
26	17.1	17.9	35.0	455
27	17.5	17.3	34.8	455
28	17.7	17.3	35.0	455
Total	473.2	488.5	979.2	---
	$\bar{t}$ = 17.53	$\bar{t}$ = 17.45	$\bar{t}$ = 34.97	$\bar{x}$ = 455.29
	S_t = 0.388	S_t = 0.352	S_t = 0.192	S_x = 1.182

*Flowmeter setting = 2000 gal/sample.
Head = 0.4 ft.
Flowmeter gave 114.38 gal/min.
Weir equation gave 113.55 gal/min.
Battery power.
Room temperature is 21°C.

Table 18. FLOWMETER TESTS, RUN #15*

Sample number	Cycle time t (min)	Volume x (ml)
1	---	---
2	---	536
3	6.5	Samples
4	6.6	over-
5	6.4	flowed
6	6.6	because
7	6.6	pump
8	6.5	didn't
9	6.5	reverse.
10	6.3	372
11	6.7	367
12	6.4	373
13	6.6	371
14	6.4	372
15	6.4	373
16	6.8	371
17	6.4	372
18	6.4	372
19	6.6	372
20	6.6	371
21	6.4	370
22	6.5	372
23	6.5	370
24	6.5	370
25	6.6	373
26	6.6	372
27	6.4	374
28	6.6	373
Total	169.4	---

$\bar{t}$ = 6.51 $\bar{x}$ = 371.56
S_t = 0.121 S_x = 1.617

*Flowmeter setting = 1000 gal/sample. Head = 0.451 ft. Flowmeter gave 153.48 gal/min. Weir equation gave 153.27 gal/min. Chamber temperature = 1.7°C. Relative humidity = 100%.

Table 19. FLOWMETER TESTS, RUN #16*

Sample number	Cycle time t (min)	Volume x (ml)
1	---	366†
2	6.6	365
3	6.7	367
4	6.5	367
5	6.5	365
6	6.4	367
7	6.4	368
8	6.5	367
9	6.7	370
10	6.5	367
11	6.5	363
12	6.4	367
13	6.6	364
14	6.5	367
15	6.5	365
16	6.4	365
17	6.6	368
18	6.6	368
19	6.6	365
20	6.5	367
21	6.3	366
22	6.6	365
23	6.6	368
24	6.5	352
25	6.3	367
26	6.6	364
27	6.6	367
28	6.5	368
Total	176.0	---

$\bar{t}$ = 6.52 $\bar{x}$ = 365.89
S_t = 0.102 S_x = 3.13

*Flowmeter setting = 1000 gal/sample. Head = 0.451 ft. Flowmeter gave 153.41 gal/min. Weir equation gave 153.27 gal/min. Chamber temperature = 1.1°C. Relative humidity = 100%. Sampler iced.
†Estimated.

Table 20. FLOWMETER TESTS, RUN #17*

Sample number	Cycle time t (min)	Volume x (ml)
1	---	371†
2	6.3	373
3	5.3	373
4	5.3	373
5	5.4	374
6	5.3	371
7	5.4	369
8	5.5	370
9	5.3	371
10	5.7	371
11	5.5	371
12	5.4	370
13	5.7	370
14	5.7	372
15	5.5	370
16	5.5	370
17	5.7	370
18	5.6	371
19	5.7	370
20	5.7	371
21	4.5	370
22	5.8	368
23	5.7	372
24	5.7	370
25	5.6	372
26	5.7	371
27	4.8	370
28	5.8	371
Total	149.1	---

$\bar{t}$ = 5.52 $\bar{x}$ = 370.89
S_t = 0.326 S_x = 1.315

*Flowmeter setting = 62.5 gal/sample. Head = .15 ft. Flowmeter gave 11.32 gal/min. Weir equation gave 9.78 gal/min. Chamber temperature = 36°C. Relative humidity = 68%.
†Estimated.

Table 21. FLOWMETER TESTS RUN #18*

Sample number	Cycle time t (min)	Volume x (ml)
1	---	369†
2	4.8	369
3	6.0	373
4	4.7	370
5	4.8	370
6	6.0	370
7	5.0	371
8	6.0	370
9	4.7	370
10	5.0	371
11	6.1	368
12	4.8	367
13	4.8	372
14	6.0	369
15	4.8	369
16	6.0	370
17	4.9	369
18	4.8	368
19	6.1	369
20	4.9	369
21	5.0	370
22	5.8	368
23	4.9	370
24	5.0	367
25	6.1	370
26	4.9	369
27	5.9	370
28	5.0	367
Total	142.8	---

$\bar{t}$ = 5.29 $\bar{x}$ = 369.43
S_t = 0.554 S_x = 1.399

*Flowmeter setting = 62.5 gal/sample. Head = 0.15 ft. Flowmeter gave 11.81 gal/min. Weir equation gave 9.78 gal/min. Chamber temperature = 35°C. Relative humidity = 70%. Sampler iced. Battery power.
†Estimated.